

66075
Ancient Regolith Breccia
347 grams

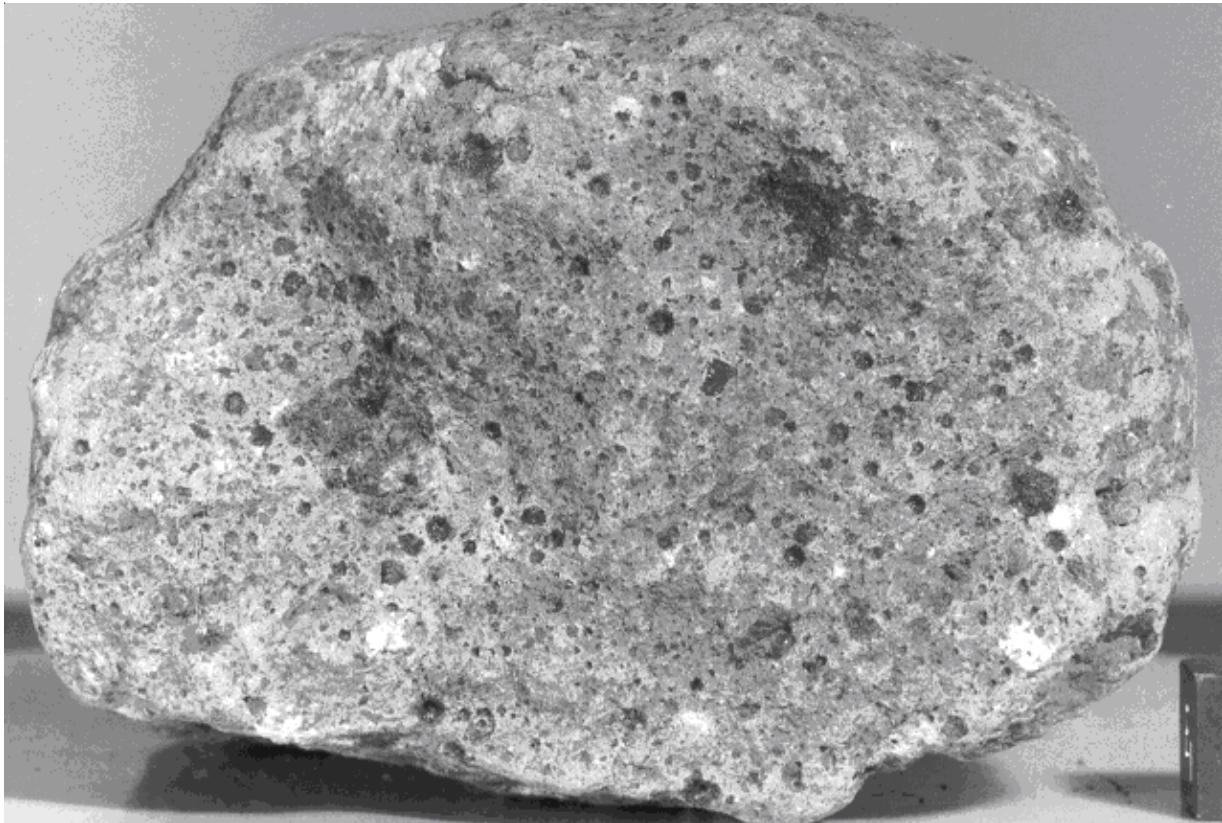


Figure 1: Photo of micrometeorite-cratered surface of 66075. NASA S72-40609. Cube is 1 cm.

Introduction

66075 is one of many coherent, light matrix breccias from Apollo 16 and has about equal amounts of both dark and light aphanitic clasts (figure 10). It was collected from the rim of a small crater at the base of Stone Mountain and has micrometeorite craters on only one side (figure 1). The matrix contains glass with a wide variety of composition. Fruland (1983), James (1981) and Korotev (1996) list 66075 as a regolith breccias and Korotev suggests that 66075 may be ejecta from North Ray Crater. The clasts have been dated at about 3.8 b.y.

Petrography

66075 is a highland regolith breccia with light grey friable matrix containing both white and dark clasts (Quick et al. 1978). The matrix is coherent, porous (20%), unsorted and seriate (5 to 200 microns) and made of angular fragments of plagioclase and other

minerals along with lithic and glass fragments. Plagioclase and devitrified maskelynite (An_{92-97}) constitute the majority of the matrix, followed in abundance by aphanites and glass.

Quick et al. (1978), McKay et al. (1986) and Simon et al (1988) found 5 – 10 % glass in the matrix. Simon et al. concluded that at least some of the glass was agglutinate, while McKay et al. found the maturity index (Is/FeO) was low (0.5). However, the rare gas data indicate a trapped solar wind component. According to Wentworth and McKay (1985), McKay et al. (1986) and Simon et al. (1988), 66075 is an “ancient regolith breccia”, because it has a high ratio of ^{40}Ar to ^{36}Ar .

Significant Clasts

The lithologies which have been identified in 66075 are: anorthositic, gabbroic anorthositic, noritic

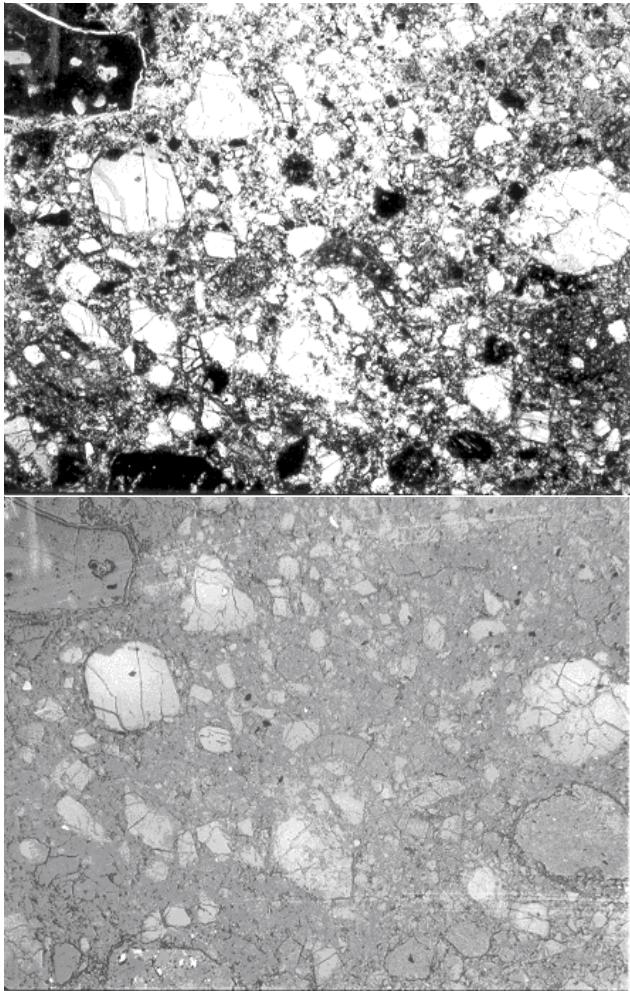


Figure 2: Photomicrographs of thin section 66075,63. Top is plane polarized light, bottom is reflected light (with internal reflections). About 3 mm across.

anorthosite and troctolite (Quick et al. 1978). The composition of pyroxene in these clasts is presented in figure 5. Olivine ranges from $F0_{65-95}$. Plagioclase is An_{90-97} .

Mineralogical Mode for 66075

(from Simon et al. 1988)

| | 20-90 micron | 90-1000 micron |
|---------------------|--------------|----------------|
| Matrix < 20 micron | 44.4 % | |
| Mare basalt | 0 | 0 |
| KREEP basalt | 0 | 1 |
| Feldspathic basalt | 0 | 0 |
| Plutonic rock frag. | 0.3 | 3.7 |
| Granulite | 0 | 0 |
| Poik. rocks | 0.2 | 1.1 |
| Impact melts | 0.5 | 6.7 |
| Regolith brec. | 0 | 1.1 |
| Agglutinate | 0.5 | 4.7 |
| Plagioclase | 12.4 | 9.6 |
| Olivine | 2 | 0.9 |
| Pyroxene | 2 | 1 |
| Opaques | 0.2 | 0 |
| Glass | 2.6 | 4.5 |

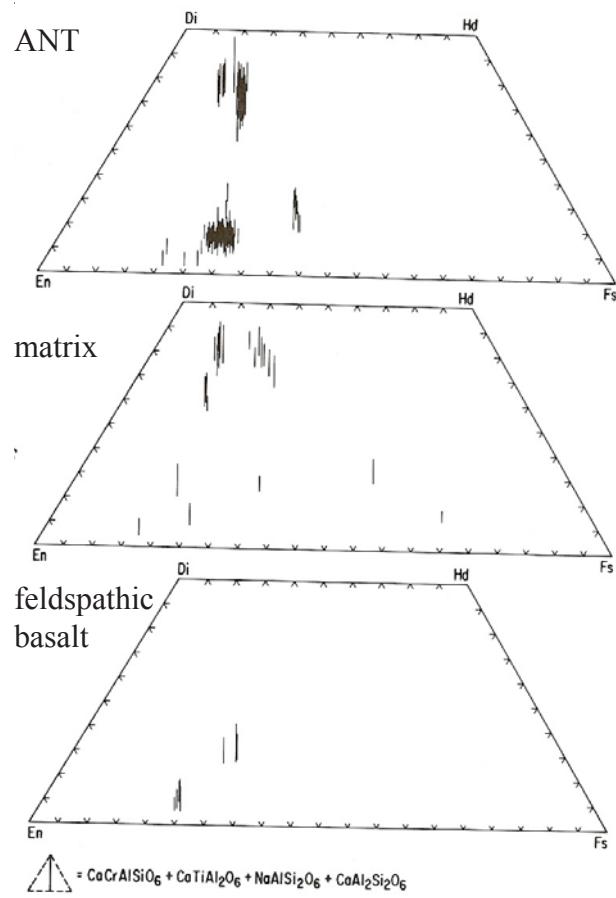


Figure 5: Pyroxene composition in 66075 (Quick et al. 1978).

Quick et al (1978) found that metal particles were ~4.5 – 5.5 % Ni and 0.05 – 2.0 % Co (meteoritic in origin). Neither Quick et al. (1978) nor Hunter and Taylor (1981) found “rust” in 66075.

Mineralogical Mode for 66075

(from McKay et al. 1986) (“Optical”)

| | >500 micron | 20-500 micron |
|---------------------|-------------|---------------|
| Mare basalt | 0 | 0 |
| KREEP basalt | 0 | 0.3 |
| Plutonic rock frag. | 10.6 | 10.4 |
| Other lithic | 0 | 3 |
| Granulite | 0.4 | 0.3 |
| Poik. Rocks | 5.7 | 1 |
| Subophitic | 69.2 | 69.2 |
| Intergranular | 4.6 | 1.7 |
| Intersertal | 0.8 | 0.7 |
| Vitric breccia | 4.2 | 5 |
| Frag. Breccia | | 0 |
| Plagioclase | 3 | 57.7 |
| Olivine | | 6 |
| Pyroxene | | 4 |
| Opaques | | |
| Glass | | 10.7 |
| Agglutinate | | |

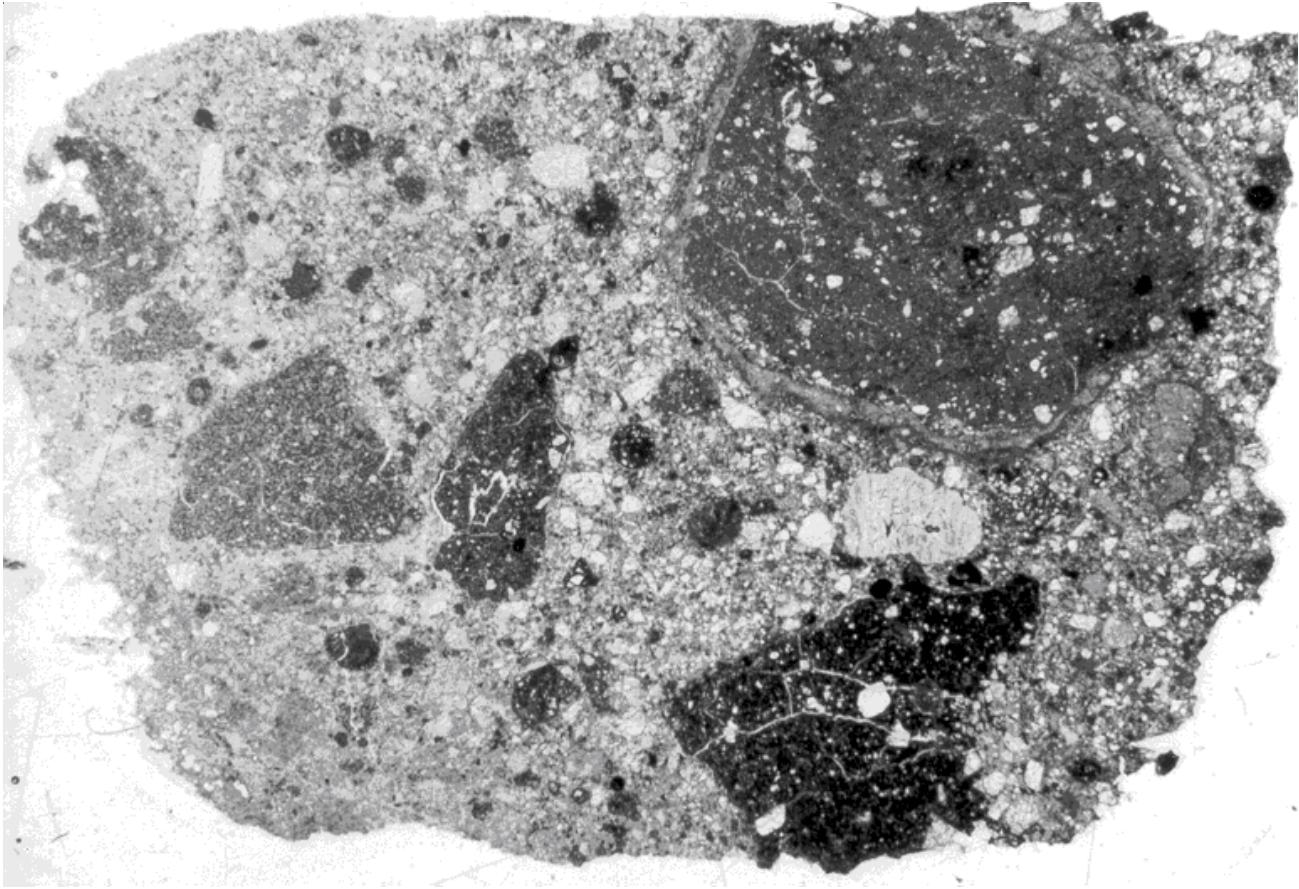


Figure 3: Thin section photomicrograph of 66075,3. Section is about 1.5 cm long. S72-43671.

Chemistry

Eldridge et al. (1973), Clark and Keith (1973), Wanke et al. (1974), McKay et al. (1986), Wasson et al. (1975), Simon et al. (1988) and Boynton et al. (1975) determined the bulk composition of 66075. Moore and Lewis (1976) reported 28 ppm nitrogen and 54 ppm carbon for 66075 (figure 4). The conclusion is that 66075 has a composition similar to the local soil where it was collected (figure 6).

Quick et al. (1978) collected data on glass fragments and small clasts within 66075 (table 2) and created a

“mixing model” to explain the matrix composition as ~20% high-Ti glass and ~80% ANT. Wanke et al. (1976) and Boynton et al. (1975) also reported results of “mixing models”.

Radiogenic age dating

Oberli et al. (1979) measured the Pb isotopes in 66075 and determined an age of 3.85 ± 10^{-5} b.y. (figure 7). Cohen et al. (2006 and 2007) studied the age of small clasts from 66075 by Ar/Ar. Oberli et al. also reported bulk Rb-Sr and Sm-Nd data and calculated model ages.

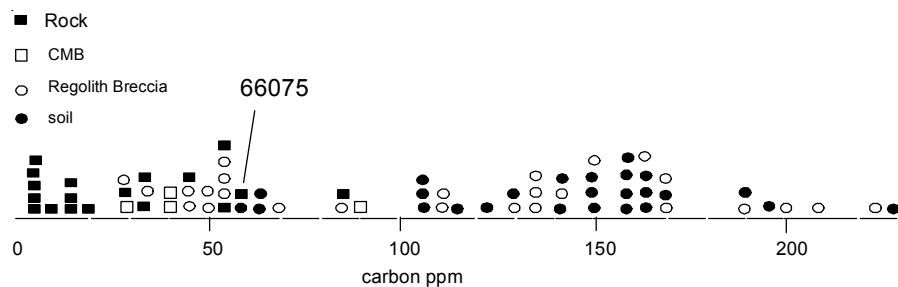


Figure 4: Carbon content of lunar samples (Moore and Lewis 1976).

Table 1. Chemical composition of 66075.

| reference weight | Miller74 Clark73 | Wanke74 | Boynton75 | Garg76 Eldridge73 | McKay 86 | Korotev96 | Wasson75 | Simon88 |
|--------------------------------|---------------------|----------|-----------|----------------------|----------|-----------|----------|----------------------|
| SiO ₂ % | 45.6 | 45.6 | (b) | | | | | |
| TiO ₂ | 0.8 | 0.45 | (b) 0.17 | (a) | 0.77 | | | 0.79 (a) |
| Al ₂ O ₃ | 28 | 26.6 | (b) 27.2 | (a) | 25.7 | | | 27.8 (a) |
| FeO | 5 | 4.7 | (b) 5 | (a) 4.6 | (a) 5.6 | 4.17 | (a) | 5.07 (a) |
| MnO | 0.06 | 0.056 | (b) 0.066 | (a) | | | | 0.068 (a) |
| MgO | 6.6 | 6.5 | (b) 6.3 | (a) | 7.3 | | | 7.5 (a) |
| CaO | 15.3 | 15.7 | (b) 16.2 | (a) | 14.6 | 15.7 | (a) | 17.2 (a) |
| Na ₂ O | 0.52 | 0.49 | (b) 0.57 | (a) | 0.505 | 0.505 | (a) | 0.51 (a) |
| K ₂ O | 0.1 | (c) 0.09 | (b) | 0.1 | (c) | | | 0.113 (a) |
| P ₂ O ₅ | | | | | 0.1 (b) | | | |
| S % | | | | | | | | |
| <i>sum</i> | | | | | | | | |
| Sc ppm | | 6.62 | (b) 7.6 | (a) 6.62 | (a) 8.63 | 6.14 | (a) | 7.7 (a) |
| V | | | | | 20 | | | 29 (a) |
| Cr | 530 | (b) 580 | (a) 489 | (a) 662 | 498 | (a) | | 635 (a) |
| Co | 25.3 | (b) 24 | (a) 27.4 | (a) 27.6 | 18.4 | (a) | | 29.9 (a) |
| Ni | 350 | (b) | | 342 | 225 | (a) 195 | 303 | (b) 440 (a) |
| Cu | 4.3 | (b) | | | | | | |
| Zn | 7.6 | (b) | | | 5.3 | 19 | (b) | |
| Ga | 5.1 | (b) | | | 4.47 | 4.51 | (b) | |
| Ge ppb | 1.7 | (b) | | | 1210 | 2100 | (b) | |
| As | 94 | (b) | | | | | | |
| Se | | | | | | | | |
| Rb | 2.01 | (b) | | | | | | 3.5 (a) |
| Sr | 200 | (b) | | 187 | 185 | (a) | | 100 (a) |
| Y | | | | | | | | |
| Zr | | | 73 | (a) 310 | 127 | (a) | | 200 (a) |
| Nb | | | | | | | | |
| Mo | | | | | | | | |
| Ru | | | | | | | | |
| Rh | | | | | | | | |
| Pd ppb | 17 | (b) | | | | | | |
| Ag ppb | | | | | | | | |
| Cd ppb | | | | | 111 | 151 | (b) | |
| In ppb | | | | | 58 | 87 | (b) | |
| Sn ppb | | | | | | | | |
| Sb ppb | | | | | | | | |
| Te ppb | | | | | | | | |
| Cs ppm | 0.12 | (b) | | 0.15 | | | | 0.15 (a) |
| Ba | 106 | (b) 90 | (a) | 186 | 101 | (a) | | 165 (a) |
| La | 11.8 | (b) 9.3 | (a) | 20.1 | 8.84 | (a) | | 17 (a) |
| Ce | 28 | (b) 28 | (a) 26.1 | (a) 52 | 22.4 | (a) | | (a) |
| Pr | 4.3 | (b) | | | | | | 44.3 (a) |
| Nd | | | 33 | | | | | 27.8 (a) |
| Sm | 5.5 | (b) | | 9.34 | 4.04 | (a) | | 7.84 (a) |
| Eu | 1.2 | (b) 1.45 | (a) 1.16 | (a) 1.345 | 1.19 | (a) | | 1.36 (a) |
| Gd | | | | | | | | 9.2 (a) |
| Tb | 1 | (b) 0.9 | (a) 0.97 | (a) 1.7 | 0.81 | (a) | | 1.5 (a) |
| Dy | 6.9 | (b) | | | | | | 10.8 (a) |
| Ho | 1.4 | (b) | | | | | | 2.2 (a) |
| Er | 4.1 | (b) | | | | | | |
| Tm | | | | | | | | |
| Yb | 3.44 | (b) 3.2 | (a) | 6 | 2.89 | (a) | | 5.1 (a) |
| Lu | 0.46 | (b) 0.51 | (a) | 0.87 | 0.396 | (a) | | 0.69 (a) |
| Hf | 3.8 | (b) 3.6 | (a) 1.5 | (a) 7.24 | 3.01 | (a) | | 5.3 (a) |
| Ta | 0.56 | (b) 0.54 | (a) | 0.84 | 0.34 | (a) | | 0.67 (a) |
| W ppb | 0.21 | (b) | | | | | | |
| Re ppb | 1 | (b) | | | | | | |
| Os ppb | | | | | | | | |
| Ir ppb | | 10 | (b) | | 8.5 | 5.5 | (a) 5.4 | 6.6 (b) 8.6 (a) |
| Pt ppb | | | | | | | | 1.7 (a) |
| Au ppb | | 7.8 | (b) | | 5.5 | 4.1 | (a) 3.2 | 5.1 (b) |
| Th ppm | 2.05 | (c) 1.6 | (b) 1.8 | (a) 1.86 | (c) 3.72 | 1.37 | (a) | |
| U ppm | 0.55 | (c) 0.41 | (b) | 0.51 | (c) 0.8 | 0.36 | (a) | 2.37 (a) 0.72 (a) |

technique: (a) INAA, (b) INAA, RNAA, (c) radiation counting

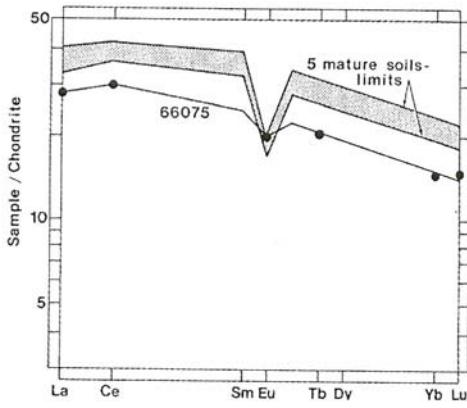


Figure 6: Normalized rare-earth-element diagram for 66075 compared with Apollo 16 soils (data from Boynton et al. 1975)..

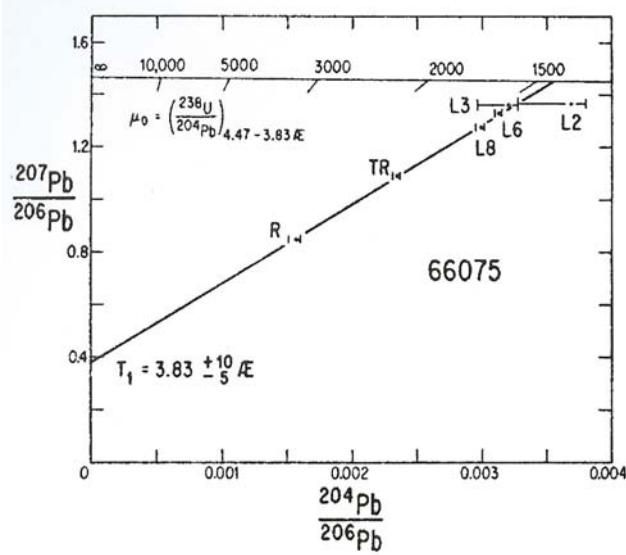


Figure 7: The age of 66075 (Oberli et al. 1979).

Cosmogenic isotopes and exposure ages

Eldridge et al. (1973) reported the cosmic ray induced activity of ^{26}Al = 130 dpm/kg and ^{22}Na = 49 dpm/kg.

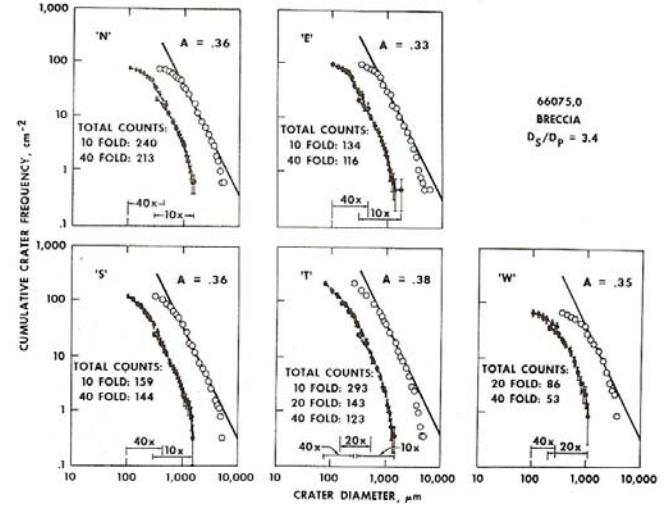


Figure 8: Density of micrometeorite craters on surfaces of 66075 (Neukum et al. 1973).

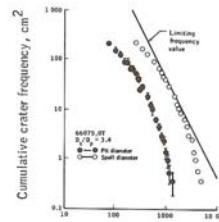


Figure 9: Density of micrometeorite craters on 66075 (Morrison et al. 1973).

Summary of Age Data for 66075

| | Ar/Ar | Pb/Pb |
|--------------------|-------|----------|
| Oberli et al. 1979 | | 3.83 b.y |
| Cohen et al. 2007 | 3.83 | |
| | 3.76 | |
| | 4.08 | |

Clark and Keith (1973) determined ^{26}Al = 149 dpm/kg, ^{22}Na = 39 dpm/kg, ^{54}Mn = 3 dpm/kg, ^{56}Co = 5 dpm/kg and ^{46}Sc = 1.3 dpm/kg.

Table 2. Chemical composition of 66075.

| reference | Quick et al. 1978 | olivine | ANT clasts |
|--------------------------------|-------------------|----------|------------|
| weight | low-Ti glass | aphanite | (a) |
| SiO ₂ % | 45.59 | 45.9 | 44.3 |
| TiO ₂ | 0.34 | 0.4 | 0.15 |
| Al ₂ O ₃ | 27 | 20 | 29.4 |
| FeO | 4.6 | 5.7 | (a) |
| MnO | 0.07 | 0.1 | 0.06 |
| MgO | 5.8 | 12.4 | 4.8 |
| CaO | 15.8 | 12.6 | (a) |
| Na ₂ O | 0.4 | 0.5 | 0.4 |
| K ₂ O | 0.07 | 0.2 | 0.01 |
| P ₂ O ₅ | 0.05 | 0.1 | (a) |
| S % | 0.03 | 0.1 | (a) |
| | 0.03 | 0.04 | |
| | | 0.1 | |
| | | 0.2 | |

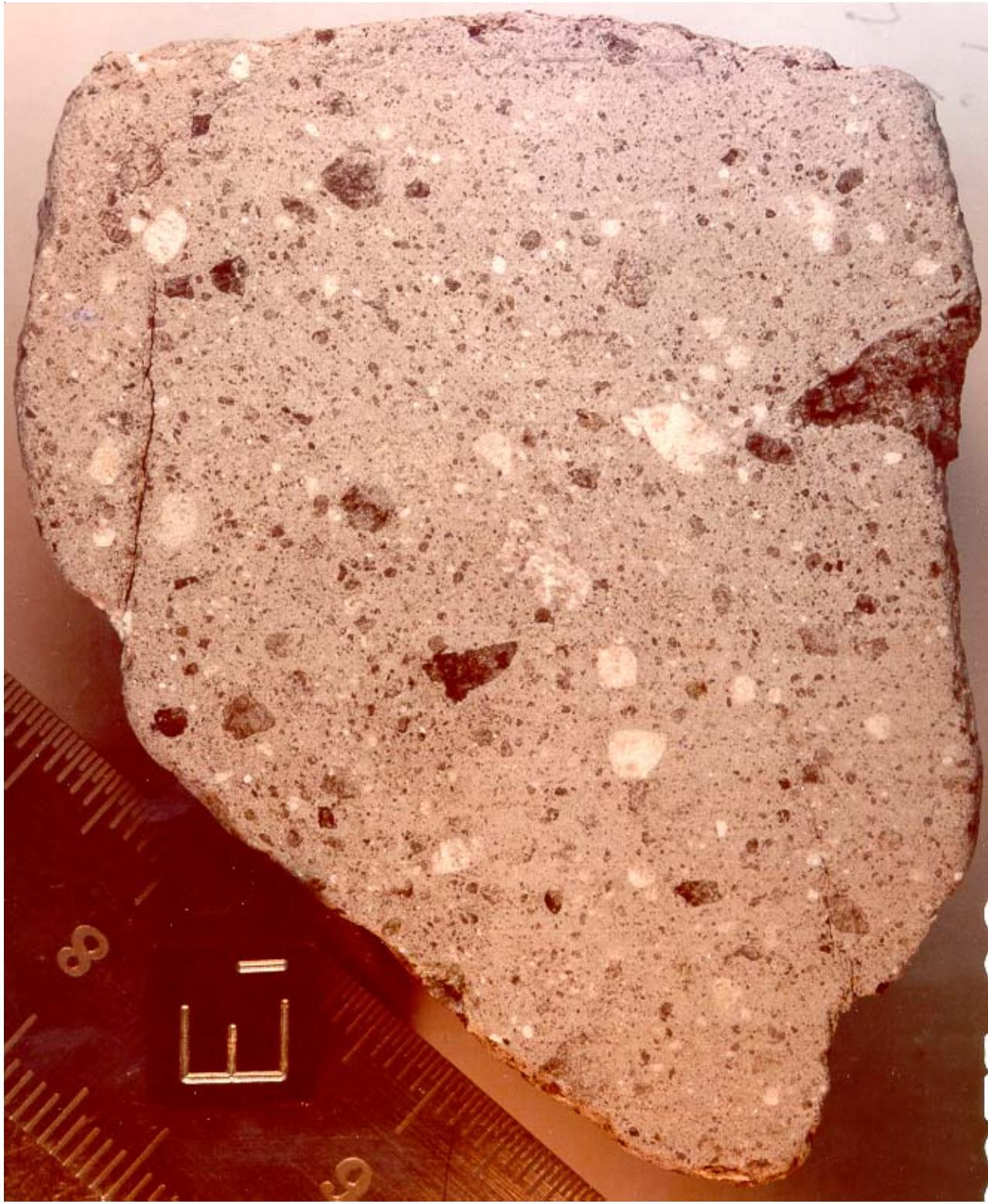


Figure 10: Sawn surface of 66075,26. NASA S78-31377. Cube is 1 cm for scale.

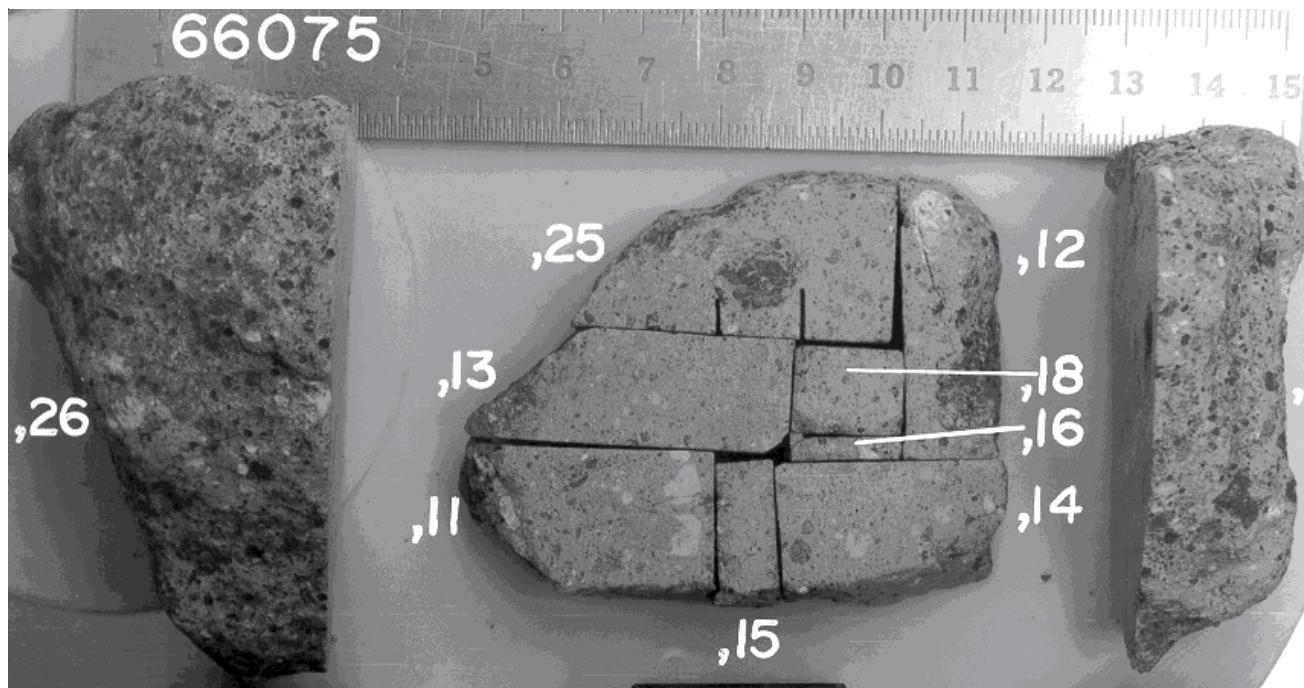


Figure 11: Slab cut from 66095. Scale is in cm.



Figure 12: Photo of 66075,26. NASA S78-31382. Cube is 1 cm.

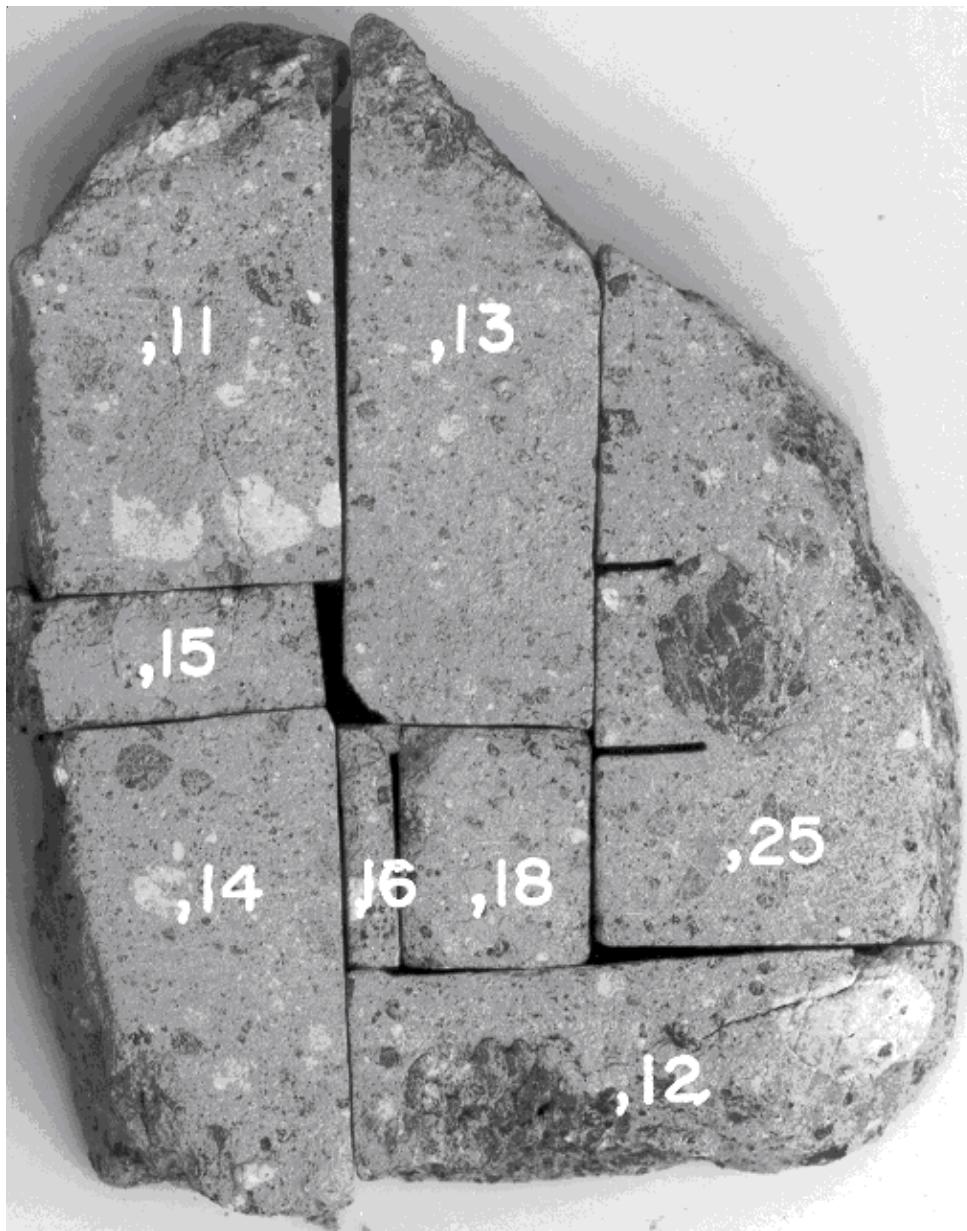


Figure 13: Photo of slab of 66075. NASA S73-28303. Central piece ,18 is 1 cm tall.

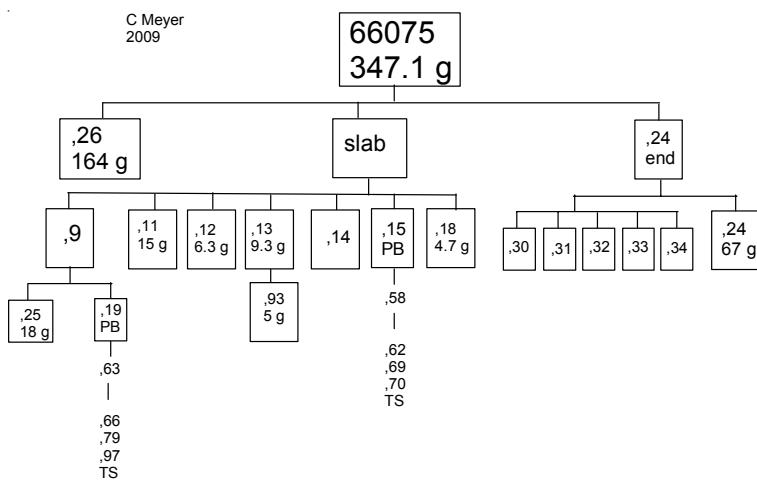




Figure 14: Sawn surface of 66075,26 as mounted for public display. NASA S88-36000.

Other Studies

Neukum et al. (1973) and Morrison et al. (1973) studied the micrometeorite craters (figures 8 and 9).

McKay et al. (1986) reported the rare gas content and isotopic ratios.

Processing

A slab was cut through the middle of 66075 (figures 10-13). The large end piece (,26) is a public display sample at the Nordlingen-Ries Crater Museum in Germany (figure 14).

References for 66075

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